07-SC-07, Project Engineering and Design (PED), Electron Neutrino Appearance (EνA) Detector, Fermi National Accelerator Laboratory, Batavia, Illinois

1. Significant Changes

Critical Decision 0, Approval of Mission Need was granted in the 1Q FY 2006. This is a new data sheet for project engineering and design funding beginning in FY 2007. No funding will be used to initiate design until approval of Critical Decision-1, Approve Preliminary Baseline Range.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007.......	1Q FY 2007	4Q FY 2007	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	10,300	2,000	N/A	12,300	N/A	12,300

4. Project Description, Justification, and Scope

This PED request provides Architect-Engineering (A-E) services for the preliminary and final design for the Electron Neutrino Appearance (EνA) Detector at the Fermi National Accelerator Laboratory (FNAL), including the EνA Near and Far Detectors and a building to house the Far Detector. The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction and detector fabrication costs based on the approved design, working drawings and specifications, and provide construction and fabrication schedules including procurements. The design effort will ensure that construction can physically start or long-lead items can be procured to support the EνA schedule.

Recent developments are beginning to unravel the mystery of the neutrinos. Perhaps the most significant development in the last several years is the discovery that the three known types of neutrinos mix with one another. The results of a number of experiments together provide convincing evidence for a quantum mechanical phenomenon in which neutrinos of one type turn into neutrinos of another type (oscillations). Neutrino oscillations can only occur if neutrinos have masses, since the rate of oscillation depends on the difference between the neutrino masses. This is indirect but compelling evidence that at

[a] The estimates in section 3 are for PED only. The full Total Estimated Cost (design and construction) of the EνA project at CD-0 ranges from $135,000,000 to $150,000,000. This estimate is based on preconceptual R&D and should not be construed to be a validated project baseline.

least two of the neutrinos have masses. What makes this particularly striking is that the masses of the neutrinos appear to involve a different physical mechanism than the Higgs mechanism believed to be responsible for the masses of the other known particles, the quarks and charged leptons. The only way the Higgs mechanism can be responsible for neutrino mass is if there is a new fundamental symmetry of nature. In either case the fact that neutrinos have masses has revealed new facets of nature that we do not yet understand.

The experimental study of neutrino oscillations also can offer the possibility of observing a difference in the behavior of matter and antimatter, or CP violation. In the early universe, equal quantities of matter and antimatter should have been created, but the present universe is filled with matter and not antimatter. A slight difference in the behavior of matter and antimatter has been observed in some decays of particles containing heavy quarks, but these effects are too small to explain the observed dominance of matter in the universe. There are interesting models for explaining the observed matter-antimatter asymmetry that involve new sources of CP violation in the neutrino interactions. Thus, it is important to look for CP violation in the neutrinos as well as continuing studies of CP violation with quarks.

So far, three types of neutrinos have been observed; electron neutrino, ν_e, muon neutrino, ν_μ, and the tau neutrino, ν_τ; and different detection techniques are required to observe the different types of neutrinos. Therefore, completely distinct experiments will be required to measure different types of neutrino oscillations.

For example, the "disappearance" of ν_μ has been observed by detecting fewer muon neutrinos at a distance from the source than would be expected if neutrinos do not oscillate. It is assumed that most of muon neutrinos from the original neutrino source (neutrino beam) oscillated to $\nu_{\tau,}$ since the detectors were sensitive enough to detect ν_e for such a rate of oscillation but not ν_τ. While the oscillation of ν_μ into ν_e, termed "electron ν appearance", may occur over long distances, the rate of such oscillation is small, and cannot be detected in current experiments.

Measurement of electron ν appearance together with the current disappearance measurement of ν_μ to ν_τ can provide the first logical step towards answering two important questions stated above - the unknown source of the mass of the neutrino, and the source of the matter-antimatter asymmetry (CP violation). Therefore, an experiment that is highly optimized to detect ν_e together with a high intensity neutrino source will be needed. In addition, such an experiment with a neutrino beam that travels a long enough distance will provide necessary information to determine the neutrino mass spectrum by measuring the subtle effects of the neutrino beam interacting with matter in the Earth.

Although we now are confident that neutrinos have masses, quantitatively we only know the differences in their masses; two of the neutrinos have similar masses and the other is either significantly heavier or lighter. However, we do not know which neutrino is heavier or lighter than the other two. Fully understanding neutrino masses will require that at least the mass of one neutrino be directly measured and that we determine whether the pair of similar mass neutrinos is heavier or lighter than the other neutrino (the "mass hierarchy"). It should be noted that the direct measurement of one of the masses will require a different technique such as using the neutrino-less double beta decay of certain nuclear isotopes.

A joint study on the future of neutrino physics was published in November 2004 by four divisions of the American Physical Society: Division of Nuclear Physics, Division of Particles and Fields, Division of Astrophysics, and Division of Physics of Beams. They recommended "a comprehensive U.S. program to complete our understanding of neutrino mixing, to determine the character of the neutrino mass spectrum and to search for CP violation among neutrinos." The report describes one required component of the program as, "A timely accelerator experiment with comparable $\sin^2 2\theta_{13}$ sensitivity and sensitivity to the mass hierarchy through matter effects."

The EνA project consists of a near detector on the Fermilab site, a far detector located 700-800 kilometers away in Northern Minnesota and a detector hall for that detector.

EνA Near Detector: The EνA near detector will operate on the Fermilab site at a distance of about 1 km from the NuMI target in the existing NUMI access tunnel. The purpose of the near detector is to measure backgrounds to ν_e identification that will appear in the far detector. The EνA near and far detectors are nearly identical. The only significant differences are the size, the clock speed of the electronics and the requirement that the near detector be mobile.

EνA Far Detector: The EνA far detector is optimized for detecting low-energy (~2 GeV) electron showers while rejecting background events. High signal efficiency and good background rejection require frequent sampling in materials with low atomic number.

The far detector is a 30,000 ton tracking calorimeter, 15.7 meter by 15.7 meter by 132 meter long. It is constructed from alternating vertical and horizontal cells of liquid scintillator contained in rigid plastic extrusion modules. A Wavelength Shifting fiber is inserted into each liquid scintillator cell and terminates on a pixel of a 32-pixel Avalanche Photo Diode (APD) chip. The APD is followed by front-end electronics that amplify, multiplex, digitize and zero suppress signals before passing them on to the data acquisition system.

Far Detector Hall: The EνA Project requires construction of a detector hall in Northern Minnesota to house the EνA far detector. The building will also include adequate space and infrastructure to facilitate construction and operation of the far detector. Most of the far detector hall will sit below grade. The exposed sides and top of the hall will be covered with a 3 meter overburden of dirt and rock to shield against cosmic rays.

Compliance with Project Management Order

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this Project Data Sheet are preliminary estimates for project engineering and design only. The preliminary schedule for project Critical Decisions is as follows:

- Critical Decision – 0: Approve Mission Need – 1Q FY 2006
- Critical Decision – 1: Approve Preliminary Baseline Range – 3Q FY 2006
- Critical Decision – 2: Approve Performance Baseline – 1Q FY 2007
- External Independent Review Final Report – 1Q FY 2007
- Critical Decision – 3: Approve Start of Construction – 3Q FY 2007
- Critical Decision – 4: Approve Start of Operations – 4Q FY 2011

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	10,300	10,300	8,300
2008	—	—	2,000
Total, Design	10,300	10,300	10,300

6. Details of Project Cost Estimate

Total Estimated Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Preliminary and Final Design	10,300	N/A

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	2,000	N/A

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	—	8,300	2,000	—	—	—	—	10,300
OPC (Design)	2,000	—	—	—	—	—	—	2,000
Total, Project Costs (Design)	2,000	8,300	2,000	—	—	—	—	12,300

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

A-E design services will be done by a combination of FNAL and competitively bid lump sum contracts administered by the FNAL. To the extent feasible, procurements will be accomplished by fixed-price contracts awarded on the basis of competitive bidding. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance will be performed by the FNAL operating contractor.

An approved Acquisition Strategy is anticipated in 3Q FY 2006 with CD-1 approval.